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THE PROBLEM OF LIQUID FUELS (FOR AIRCRAFT ENGINES).

(Summary of a lecture delivered by Professor Gino Gallo,
January 26, 1924, before the Italian Aerotechnical Association.)

From "L'Ala d'Italia," March, 1924.

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The crisis which troubles the world market for liquid fuel in general and for carburants in particular is doubtless one of the most serious ever experienced by modern industry. It is a national crisis of economic and political independence for countries like Italy and France, which have to depend almost entirely on foreign sources for petroleum. It is also a world crisis, because of the approaching exhaustion of present sources, or at least because of the evident disproportion between the total supply and the remarkably rapid increase in consumption.

During the last thirty years the production of coal has doubled in about 17 years and of petroleum in only nine years and a half. The causes of this tremendous increase are many and diverse: the widespread diffusion of machinery requiring large quantities of mineral lubricants; the invention of internal combustion engines; the sudden and remarkable development of automobiles and aircraft and, lastly, the adoption of liquid fuel for both the military and merchant marine, the chief cause of the latter being the Anglo-American rivalry.

* From "L'Ala d'Italia," March, 1924, pp. 63-65.

The latest and most accurate researches of specialists indicate that the world reserves of petroleum are about 70 billion barrels, of which only 9 billion barrels are in the United States, which has accordingly already consumed 40% of its original supply. No fear is entertained, however, of an early exhaustion of the coal deposits, which were estimated in 1913 at 73 billion tons, but the question of the petroleum reserves presents, on the contrary, a very serious problem, since, if no new deposits are found and if the consumption continues at the rate of the year 1922 (851 million barrels), the known deposits will last only about 80 years. But if the consumption increases at the rate it has for the last few years, the 70 billion barrels (about 10 billion tons) of petroleum will be exhausted by 1950 and the special reserves of the United States will last hardly ten years. Hence the intensified search for petroleum deposits in all countries, including Italy with the financial aid of the government, although our country has thus far seemed to be particularly devoid of this valuable fuel. This eminently aleatory search may perhaps be successful in the more or less distant future, but economic and prudential considerations demand an immediate solution of the problem, which is now disturbing the countries unprovided with petroleum and which, before many years, will be of prime importance for the whole world.

The solutions suggested for meeting the lack of liquid fuel may be summed up under two general heads:

1. The economical use of the petroleum now available, by a better utilization of all its components;
2. Creation of petroleum substitutes from natural sources within the country.

Cracking.— The neglect of an American workman to watch his retort in continuing the distillation above 300°C (572°F) led to the discovery of the so-called process of "cracking." This process, which is carried out with a free flame and under ordinary pressure, is a kind of pyrogenetic degradation of the less volatile long-chain hydrocarbons, with the formation, on the one hand, of the more volatile short-chain hydrocarbons (even down to methane and hydrogen) and, on the other hand, of carbonaceous and piceous deposits formed by the condensation of the unsaturated hydrocarbons. The proportion of gasoline obtained is therefore always rather low, never amounting to more than 30%. The Standard Oil Company produced in 1919, by cracking, over 237 million gallons of artificial gasoline.

The fact that the process of cracking can be applied only to the fractions of natural petroleum which boil above 300°C and which are not very abundant and are valuable for their combustible and lubricating derivatives, has led to the endeavor to convert the less rich and more abundant intermediate fractions existing in kerosene, into light oils.

The catalytic process, proposed for this purpose by Sabatier

and Maille and which is employed in a Brussels plant, consists in causing the vapors of the intermediate oils to pass over metal catalyzers, like nickel, heated to the proper temperature. The oils are thus largely converted into liquids which boil under 160°C (320°F) and which consist of unsaturated and aromatic hydrocarbons. These products, however, like the rest of the light oils obtained by cracking, tend to resinify, on exposure to air and light, and are therefore unsuited for long keeping. This process yields a considerable quantity of gas, accompanied by incrustations in the retorts which constitute one of the principal industrial disadvantages.

Dr. Bergius in Germany, however, caused the pyrogenetic degradation of the hydrocarbons in the presence of an excess of hydrogen, under a pressure of 100 atmospheres and at a temperature of 400°C (752°F), and succeeded in converting into light oils not only the intermediate oils but also the asphaltic and piceous residues of the petroleum without the formation of solid residues.

We now come to the processes for obtaining light oils from other natural sources, such as coal, lignite and bituminous schists.

The products of the destructive distillation of coal vary greatly both in quality and quantity, according to whether the distillation is completed at a low temperature, about 500°C (932°F), or at a high temperature, around 1000°C (1832°F). The distillation at a low temperature yields as high as 12% of tar,

consisting half of saturated and aromatic hydrocarbons similar to natural petroleum, and half of organic acids such as the phenols. The latter may be converted, however, as demonstrated by Dr. Fischer, into saturated hydrocarbons by hydrogenation under pressure at 700 to 800°C (1292-1472°F) in the presence of tinned sheet-iron. This process, though so promising in the laboratory, encountered in practice, however, serious difficulties of a technical and economic nature, so that it has not been industrially adopted.

Among the products of the destructive distillation of coal are benzene (also known as "benzol"), naphthalene and a tetrahydrogenated derivative of the latter, "tetrolina," a liquid hydrocarbon with a heating power of 11600 calories. But however great an effort is made to increase the production of benzene and naphthalene, these compounds can amount to only a very small portion of the liquid fuel required and their contribution to the solution of the fuel problem is therefore very slight.

Of greater promise is the process proposed by Bergius, of starting directly with coal and effecting its liquefaction with hydrogen. According to the statements in the patent, by subjecting powdered coal in the presence of hydrogen to a pressure of 200 atmospheres and a temperature of 400°C (752°F), he succeeded in liquefying 50% of the coal with a consumption of only 3-4% of pure hydrogen. The essential question, however, regarding this marvelous process is whether it can be transferred from the labor-

actory to the factory, thus rendering it possible to manufacture synthetic petroleum on a large scale.

All the processes thus far described presuppose the existence of large reserves of the raw materials, that is, of coal, of which Italy is completely destitute, and of petroleum, the production of which is now almost negligible.

Italy, however, has mountains and a sunny climate, two factors which assure her an important position in the future economy of the world, since the solar energy which, on the one hand, raises vast quantities of water to the summits of the Alps, enables us to utilize continuously a great and inexhaustible source of energy and, on the other hand, this same energy places Italy in a position of supremacy from the agricultural viewpoint.

In order to utilize this solar energy, various methods may be adopted. First of all, from a general viewpoint, it is necessary to enlarge our wooded areas and promote their development. In the second place, our hydroelectric energy may be used for the direct synthesis of liquid fuel from its elements, or rather from the products of combustion, carbon dioxide and water. This process, which was originated by the writer several years ago, has at present only a theoretical value, but when this goal is attained the troublesome problem of liquid fuel will be solved in a manner not unlike that in which the nitrogen problem has been solved. In the third place, there is the direct utilization of the carbon compounds contained in vegetation and obtainable from it.

Under the last head comes ethyl alcohol, which is obtained by the fermentation and distillation of various vegetable substances. Alcohol will perhaps constitute the solution of the problem for agricultural countries like Italy, France and Spain. It has already been partially adopted in France, which, after much study and experimentation by a special commission, settled on the formula of 90% of gasoline and 10% of absolute alcohol and made it obligatory by law for importers of gasoline to buy from the government (which holds the monopoly of alcohol) a quantity of alcohol equal to 10% of the gasoline imported. The difficulties arising from the non-mixability of 95% alcohol with gasoline have been overcome, either by employing additional solvents or by new methods of perfectly dehydrating the alcohol, in consequence of which the employment of mixtures containing 40-50% of absolute alcohol is reported.

During the war, the Germans used various mixtures of alcohol, gasoline, ether, acetone and kerosene. The English still use "Natalite," a mixture of alcohol and ether with 5% of ammonia. In Italy, even before the war, Purgotti proposed "eterol," a mixture of alcohol and ether with 5% of oil of vaseline and Sesti offered a fuel consisting of 80% of alcohol and 20% of carbon disulfid.

Regarding the serious disadvantage of the calorific inferiority of alcohol to gasoline (6850 : 11000), it appears possible, from past experiments, to offset this almost completely by the em-

ployment of special high-compression engines, thus increasing the dynamic output of the alcohol without danger of premature spontaneous ignition.

After assuming the above solution of the problem, the two conditions of the production and cost of the alcohol must still be satisfactorily met. The present production of alcohol in Italy is about 500,000 hectoliters (13,209,000 gal.), obtained almost entirely from molasses and poor wine. This is about one-third of the quantity of gasoline consumed in Italy in 1921. A further quantity of at least 300,000 hectoliters (7,925,400 gal.) of alcohol served in other forms for industrial uses and alcoholic beverages.

The production of alcohol could, however, be easily increased by resorting to other raw materials, such as spoiled cereals, Indian figs, beets and carob beans. Furthermore, Italy could obtain from her colonies, other raw materials for the manufacture of alcohol, such as (for example) the prickly, which is cultivated on a very large scale in the Orange Free State and which yields 1200 liters (317 gal.) of alcohol per metric ton (2204 lb.) of the fruit.

There still remains the question of cost. With present engines, the consumption of alcohol is about 1.4 times greater than the consumption of gasoline. The cost of alcohol should therefore be 1.4 times smaller than that of gasoline, i.e., with gasoline at 280 lire per hectoliter, the price of alcohol should not

exceed 200 lire, including the tax. The present price of alcohol on the Italian market is, however, about 300 lire per hectoliter, plus the tax.

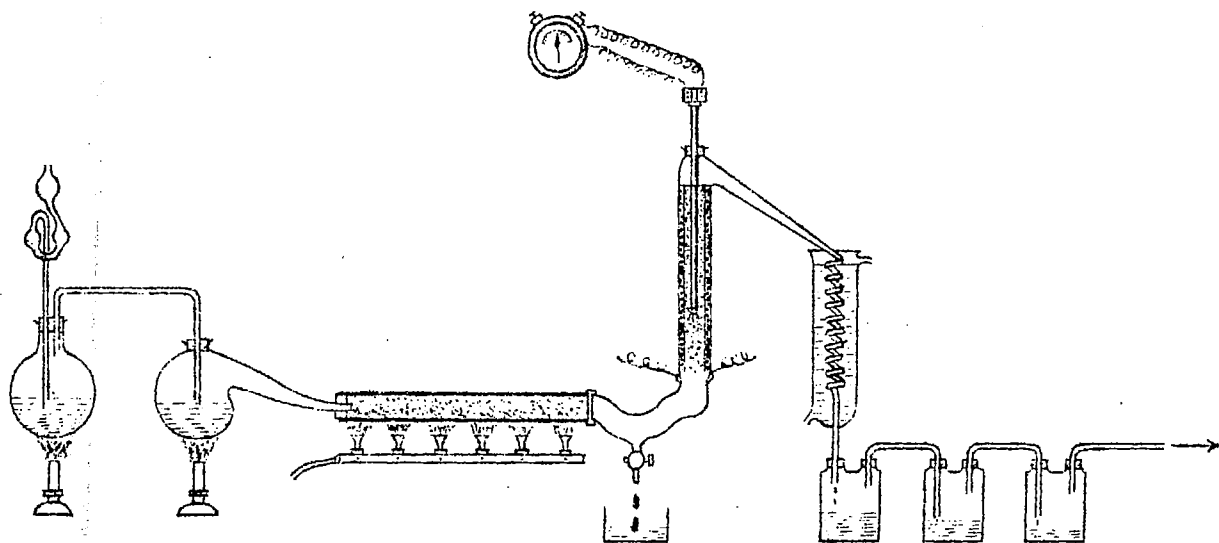
It is strange that the price remains so high when it is known that for the past year there is an unsold surplus of about 150,000 hectoliters (3,962,000 gal.) of molasses alcohol and that there is a prospect of about twice as much this year. There is, therefore, no occasion for taking the present market price as the basis, while it can be determined to what point we can sacrifice, for the safety of the nation and the improvement of its economic balance, the possible greater cost of a fuel produced by our own farmers.

Lastly, attention should be called to the proposal of Maihle in France to utilize the energy of vegetation in the preparation of gasoline and petroleum from vegetable oils, such as peanut-oil, rape-oil, linseed-oil and castor-oil. It is a kind of catalytic cracking process applied to vegetable oils at normal pressure, excepting that the complex chemical constitution of vegetable oils and the presence in them of oxygen which must be eliminated, requires the use of correspondingly complex dehydrating and hydrogenating catalyzers. The promising researches initiated by the writer in collaboration with Dr. Corelli, though of a similar nature to those of Maihle, differ from the latter in several essential details. These experiments yielded gases of high heating power and liquids up to 65% of the oils employed. These liquids are very volatile, of a yellowish color and aromatic odor, somewhat

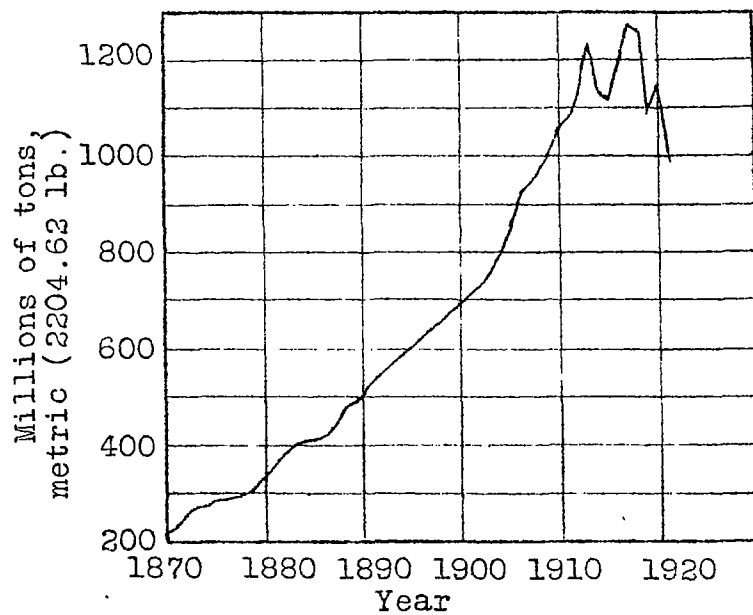
fluorescent, almost neutral and consist of hydrocarbons which distil, for the most part, below 300°C (572°F). These preliminary researches do not, as yet, warrant definite conclusions, but give promise of ultimately leading to concrete results. In any event, this method presents one of the means at our disposal for the direct utilization of the solar energy stored in the oleaginous seeds of plants whose cultivation can be readily increased in Italy and the Italian colonies.

Italy's liquid-fuel problem is not simply a chemical problem, but also a mechanical, economic, agrarian and, above all, a political problem, whose correct solution depends on the proper valuation of all these aspects.

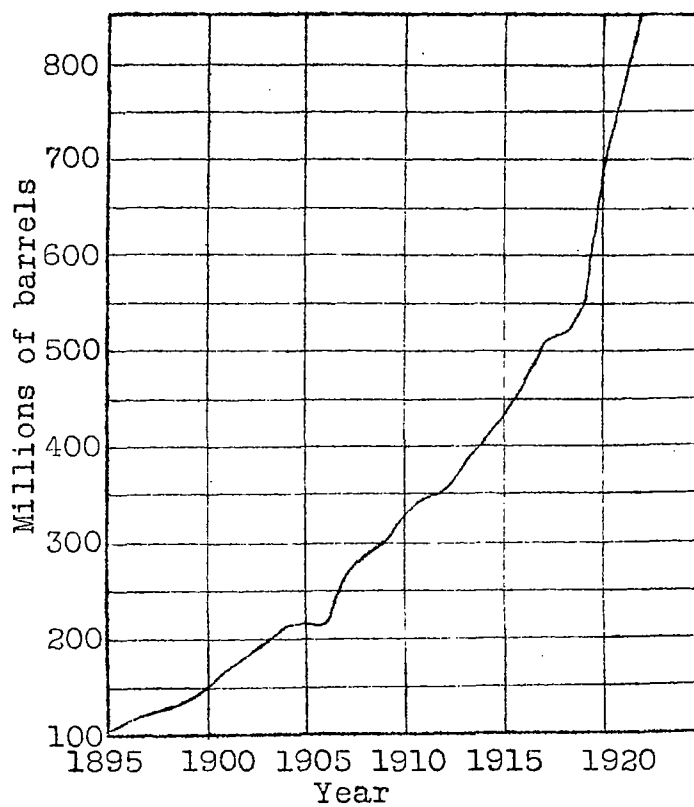
Translation by Dwight M. Miner,
National Advisory Committee
for Aeronautics.



Galli-Corelli apparatus for the decomposition of vegetable oils.

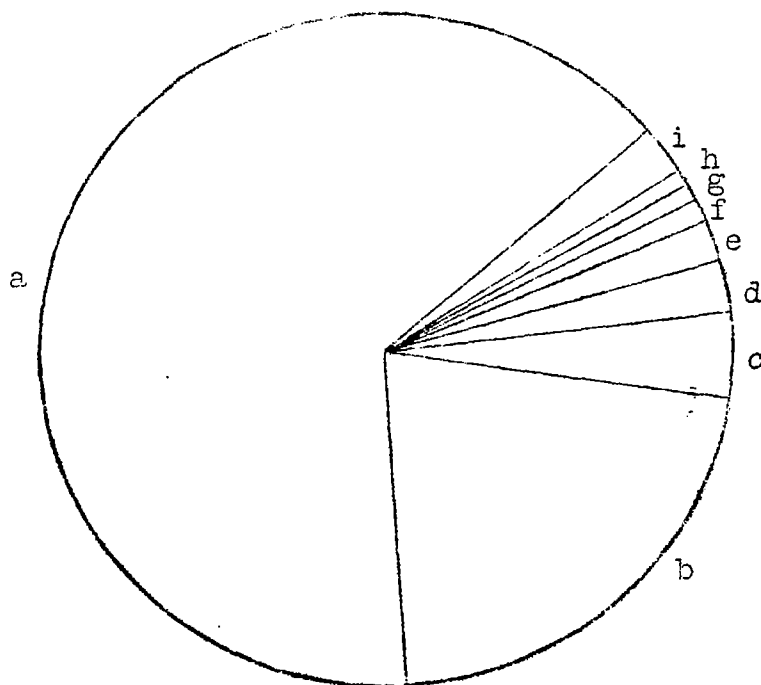


World production of coal



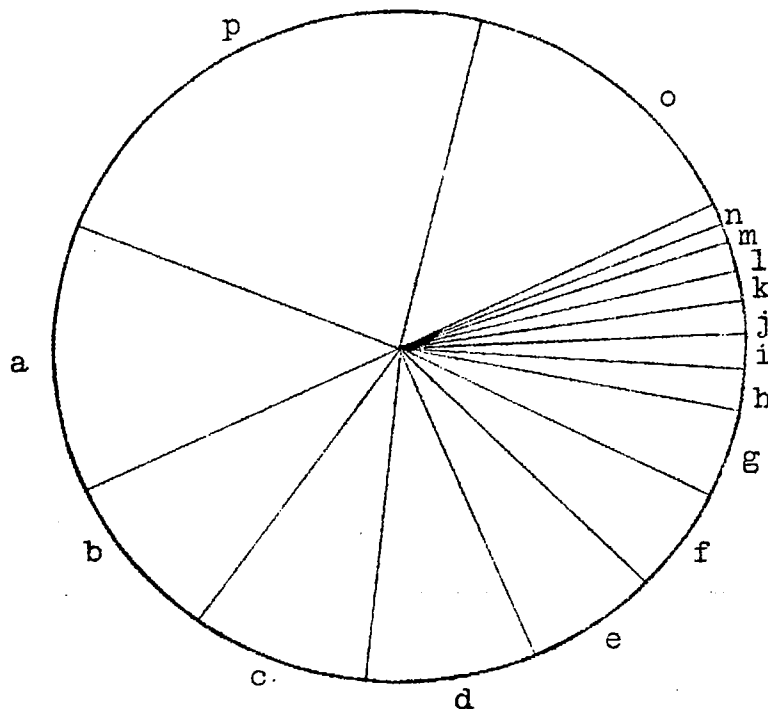
World production of petroleum

Country	Number of barrels	%
a=United States	551,197,000	64.6
b=Mexico	185,057,000	21.7
c=Russia	35,091,000	4.1
d=Persia	21,154,000	2.5
e=Dutch East Indies	16,000,000	1.9
f=Roumania	9,817,000	1.1
g=Burma	7,930,000	.9
h=Peru	6,342,000	.9
i=All other nations	18,902,000	2.3



Distribution of world production of petroleum in 1922=
851,540,000 barrels.

Country	Millions of barrels	%
a=United States & Alaska	9170	13.1
b=Southern Russia & Caucasus	5810	8.3
c=Persia & Mesopotamia	5810	8.3
d=Peru, Ecuador, Columbia & Venezuela	5740	8.2
e=Mexico	4480	6.4
f=Argentina, Bolivia & Chile	3570	5.1
g=Dutch East Indies	3010	4.3
h=China	1400	2.0
i=Japan & Formosa	1260	1.8
j=Roumania & Galicia	1120	1.6
k=Burma	980	1.4
l=Canada	980	1.4
m=Algeria & Egypt	910	1.3
n=Northern Russia	910	1.3
o=Estimated margin	10010	14.3
p=Unaccounted for	14840	21.2



Distribution of world reserves of petroleum at the beginning of 1922=70000 million barrels.

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